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SCIENTIFIC AND POLICY CONSIDERATIONS IN RESTORATION AND REINTRODUCTION OF ENDANGERED SPECIES

DONALD A. FALK AND PEGGY OLWELL

"*Restoration, hang thy medicine on my lips.*"
—*King Lear,* Act IV, Scene 3

Like Cordelia's impassioned prayer in the closing moments of Shakespeare's greatest tragedy, the world of conservation is turning increasingly to the healing powers of ecological restoration for salvation. At least three national organizations—Society for Ecological Restoration, Natural Areas Association, and Restoring the Earth—are devoted to promoting intensive habitat management and ecological restoration as strategies for conserving biological diversity. Federal land-managing agencies as well as the largest private land conservation organizations, notably The Nature Conservancy, are engaged increasingly in various forms of reintroduction and restoration practice. Many members of the national Center for Plant Conservation network are playing an active role in replacing extremely rare and threatened species back into natural areas. Even the mainstream media have taken notice (Nash, 1991), as have many corporations whose activities have a major impact on the land and the life it supports.

But is reintroduction always a feasible or appropriate tool with which to perpetuate biological diversity, ecological processes and the grand dance of evolution? Experience reveals that reintroduction efforts frequently encounter substantial technical obstacles and may entail such a high degree of uncertainty that their value as a tool for conservation can be questionable. The biological value of reintroduction remains largely a matter of informed speculation, although the evidence supports cautious optimism. And the strategic and political implications of an improved ability to translocate plants are just beginning to be understood, including the chilling possibility that reintroduction will, through its application in mitigation programs, rationalize and even facilitate the destruction of existing natural areas.

In the face of such uncertainty and peril, why are conservationists thinking at all about moving or transplanting rare species?

At least three environmental conditions compel consideration of this activity:

1. Continued Destruction of Habitat

Despite decades of heroic effort, the continent's remaining undisturbed natural areas continue to be strip mined, logged, paved and fragmented. The Nature Conservancy—the most successful and most important private land conservation organization in the history of the country—has managed to protect on the order of 5 million acres, amounting to approximately .22% of the land area of the United States. Many states with the highest indices of plant diversity, including Hawaii, California, Texas, Florida and Puerto Rico, have major areas of habitat (encompassing whole endemic community types) on land that is unprotected and under active commercial development. In the state of Hawaii alone, as many as 95 *new* golf courses are proposed and awaiting construction permits to consume some of the last remaining level lowland habitat in the islands (Hawaii Office of State Planning, 1991). Wallace (1990) describes an analogously critical context for the sand scrub communities of central peninsular Florida. Pressure is increasing in many states to open public lands for large-scale strip mining for minerals; substantial lands are owned privately by mining corporations with plans for operations covering hundreds of thousands of acres. Equally intense pressure exists in tropical regions (e.g., Holden, 1986).

In the face of such destruction, rare plants are inevitably the first to suffer. Of the approximately 20,000 plant taxa native to the United States, 4412 (22%) are in the top endangerment categories in the ranking systems of the U.S. Fish and Wildlife Service, The Nature Conservancy, or the Center for Plant Conservation (Center for Plant Conservation 1992). Of these plants, 2768 (about two thirds) are restricted to a single state or province. Hawaii has 547 endemic rare taxa. The California Floristic Province includes 4450 taxa of plants, of which 2140 (48%) are endemic to the region (Myers, 1990). On a continental basis, 1183 (39% of the total flora) are known from five or fewer populations or from 1000 or fewer individuals. Not surprisingly, these taxa have the least margin of survival in the face of habitat loss and the greatest vulnerability to extirpation of populations and the loss of evolutionary viability. Even where entire species have not been driven to extinction, many species are becoming severely depleted due to loss of genetically distinct populations. As Ehrlich (1991) observes, "extirpation of populations is the dominant element of the extinction crisis in temperate regions today and most severely threatens ecosystem services in these areas."

2. Habitat Degradation

Even where land is formally protected from outright destruction, significant deterioration of habitat can occur and with it the loss of the ability of many plants to adapt and survive. For instance, well over two-thirds of the total land area of the United States west of the Rocky Mountains is owned and managed by various agencies of the Federal government—Bureau of Land Management, U.S. Forest Service, National Park Service, Department of Defense—as well as the significant acreage reserved for Native American Indians, primarily in the southwest. Many of these lands are severely overgrazed, eroded, logged and overrun with recreation vehicles. Biological invasion by exotic organisms can so thoroughly alter habitat characteristics that the composition of entire communities is altered (Vitousek et al., 1987; Brockie et al., 1988; Vermeij, 1991). Millions of acres of Great Basin and northern Great Plains grasslands, for example, have been invaded and altered by exotic grasses such as red brome (*Bromus tectorum*) and other exotic species, reducing the native perennial bunchgrass communities.

Many rare plants are endemic to specific community types, or restricted primarily to specific seral stages. Fiedler (1986; Fiedler and Ahouse, 1992) and others (Kruckeberg and Rabinowitz, 1985) have described a variety of patterns of rarity, including such ecological and evolutionary factors as the relationship of edaphic endemism and restricted ecological amplitude to geographic rarity. Habitat endemics, a category that includes a large proportion of rare American plants, are often sensitive to alteration of physical or biotic characteristics of site and hence vulnerable to decline even if the site has not been completely or visibly "destroyed."

3. Large-Scale Climate Change

As Peters (1988) has described, current trends of climate change may render many protected areas unsuitable to maintain the species that presently occur within their boundaries. Correspondingly, as the appropriate climatic zones for species migrate toward the poles, the optimal range for many plants will shift into areas of land that are currently unprotected. Much of this change is projected to occur at a rate tens or hundreds of times faster than plant populations can "migrate" generationally across the landscape (Schwartz, 1992).

These effects will likely be most severe for species that are restricted in their geographic distribution and ecological range. For example, species found in coastal areas, wetlands, montane-alpine and arctic biomes, and microclimatic refugia (such as the Appalachicola River Basin of Florida and southern Georgia) stand to experience drastic reduction or movement of their preferred habitat. The same would be true for the Hawaiian flora, which is more than 95% endemic to the Islands; many taxa are found on only a single island, at specific elevations and aspects to prevailing wind directions. Species occurring in few sites or in small populations will be the most vulnerable, a category that (as noted above) includes as many as two-thirds of all sensitive species in the United States. If these species are to survive at all, serious and active intervention into their management, including intentional alteration of their geographic distribution, will be essential. Combined with the effects of habitat destruction and degradation, many of these plants will not survive without such measures.

These three factors, among others, suggest that reintroduction and restoration will play a vital role in conservation strategies in the coming decades (Falk, 1990b; Edwards, 1990; IUCN, 1992; McMahan, 1990). Limited experience suggests that these methods may provide an enormously positive supplement to land protection, especially in helping to preserve individual populations. Such developments, however, do not take place in a political vacuum. Many of the societal forces contributing to the destruction of natural areas are seizing on the ability to translocate organisms as a way to rationalize or facilitate further destruction of habitat, rather than as a tool to repair damage that has already been done. Continuing threats to the Endangered Species Act, and to the basic legislative provisions for the protection of land in its natural state, will make such misuses of reintroduction even more dangerous. Certain regions of the country, notably southern California, peninsular Florida, and coastal Hawaii, are already experiencing such overwhelming population growth and development pressure that the few regulatory restrictions protecting land seem like a fragile dam about to burst. When this happens, whether in a continuing trickle of incremental loss of habitat or a catastrophic deluge, the ability to reintroduce species will play a pivotal role in the survival of many species. The question will then become: when all of the suitable land has been destroyed, where can they be introduced?

REINTRODUCTION AND THE U.S. ENDANGERED SPECIES ACT

The Endangered Species Act of 1973, as amended, provides the legislative authority for the use of reintroduction as a conservation tool in the recovery process for federally listed endangered and threatened species (U.S. Fish and Wildlife Service, 1988). However, reintroduction has been controversial from both the economic and scientific perspectives. It was the economic conflicts and concerns that prompted Congress in 1982 to amend the Act to include a special provision for experimental (reintroduced) populations (Drabelle, 1985).

Within Section 10(j) of the Act (U.S. Fish and Wildlife Service, 1988), experimental populations are allowed to further the conservation of the species. An experimental population may be classified as either "essential to the continued existence of the species" or "nonessential." If the reintroduced population is deemed "essential," then the population is treated (for purposes of the Act) as though it is a threatened species. Thus, the population is awarded all the protection of a threatened species under the Act. However, if it is deemed "nonessential," then it is treated as though it is a proposed species under the Act, thereby receiving less protection than the essential population. These designations allow the U.S. Fish and Wildlife Service more options in managing the reintroduced populations.

Since 1982 when these amendments were developed, only seven experimental populations have been listed under the Act; all have been for vertebrate animals (J. Sheppard, pers. comm.). However, plant reintroductions are occurring regularly without formal listing as experimental populations under the Act. Instead, they are being conducted without the legal designation of the Act through multi-agency and/or private cooperative efforts.

Table 1. Recovery plan status of 239 federally listed plants, as of 1990.*

Plan status	No.	(%)
Approved	119	(50)
Draft	71	(30)
None	49	(20)
Total	239	(100)

* Source: U.S. Fish and Wildlife Service (1990a).

In a review of plant recovery plans for their report to World Widlife Fund, Cook and Dixon (1989) found that the predominant threat to rare plants, not surprisingly, is habitat disturbance or destruction. Sixty-six percent of the species they reviewed were threatened by loss of habitat. Thus, site preservation should be the first priority in a recovery plan. However, the authors also indicated that the second priority in developing a recovery program for rare plants should be "the identification of potential habitat and the development of techniques to establish new populations." Obviously, Cook and Dixon view the reintroduction of endangered plants as a viable means of enhancing the conservation of these species.

There are others who believe reintroduction can be beneficial to the recovery of endangered plant species (*see* Jones, 1990). For example, the U.S. Fish and Wildlife Service's 1990 report to Congress revealed that for the 239 listed plants, only 50% (119) had approved recovery plans and 30% (71) had draft recovery plans (Table 1). However, reintroduction was either in progress or planned as part of the recovery efforts for 56 listed plants (Table 2). Additionally, of those 56 species, 42 had reintroduction as one recovery criterion for downlisting or delisting the species. Therefore, almost 25 percent of the federally listed plants, as of 1990, have reintroduction as a tool for the recovery of the species (U.S. Fish and Wildlife Service, 1990a). This number of species with reintroduction as a major focus or effort for recovery is surprisingly large, especially considering that the U.S. Fish and Wildlife Service does not have a specific policy on rare plant reintroductions or guidelines on how to conduct rare plant reintroductions (U.S. Fish and Wildlife Service, 1990b). Essentially, the Service's only policy guideline on reintroductions is that they should not occur outside the historic range of the species unless approved by the Director (U.S. Fish and Wildlife Service, 1990b).

Table 2. Federally listed plant taxa with reintroduction projects, as of September, 1990.*

Taxon	Current[1]	Planned[2]	Down/De-listing Criteria[3]
Amorpha crenulata			X
Amsinckia grandiflora	X	X	X
Amsonia kearneyana	X		
Arctostaphylos pungens ssp. *ravenii*	X		X
Asimina tetramera	X	X	X
Astragalus phoenix			X
Astragalus robbinsii var. *jesupi*			X
Banara vanderbiltii			X
Betula uber	X		X
Boltonia decurrens	X	X	X
Buxus vahlii			X
Calyptronoma rivalis	X	X	
Centaurium namophilum			X
Cornutia obovata			X
Crescentia portoricensis			X
Cyathea dryopteroides			X
Daphnopsis hellerana			X
Dicerandra immaculata	X		X
Enceliopsis nudicaulis var. *corrugata*			X
Geum radiatum	X	X	
Goetzea elegans			X
Grindelia fraxinopratensis			X
Harperocallis flava	X	X	X
Hibiscadelphus distans		X	
Hymenoxys acaulis var. *glabra*	X		X
Hymenoxys texana			X
Ilex cookii			X
Iliamna corei		X	X
Isotria medeoloides			X
Ivesia eremica			X
Kokia cookei	X	X	
Lesquerella filiformis	X		
Liatris helleri			X
Mahonia sonnei			X
Mentzelia leucophylla			X
Nitrophila mohavensis			X
Oxypolis canbyi			X
Panicum carteri		X	
Pedicularis furbishiae			X
Pediocactus knowltonii	X	X	X
Pediocactus pebblesianus var. *pebblesianus*			X
Peperomia wheeleri			X

Table 2. Continued.

Taxon	Current[1]	Planned[2]	Down/De-listing Criteria[3]
Phacelia argillacea		X	X
Potentilla robbinsiana	X	X	X
Ranunculus acriformis var. *aestivalis*		X	
Rhus michauxii	X	X	
Sarracenia oreophila	X	X	
Sidalcea pedata			X
Solidago spithamaea			X
Stephanomeria malheurensis			X
Styrax texana	X		
Thelypodium stenopetalum			X
Torreya taxifolia			X
Trichilia triacantha			X
Trifolium stoloniferum		X	
Zanthoxylum thomasianum			X
TOTALS	18	17	44

* Source: U.S. Fish and Wildlife Service (1990a).

[1] Any reintroduction project occurring in the past few years (1986–1990) or since any previous reports.

[2] Any reintroduction project to be continued or initiated during 1991 and 1992.

[3] Any reintroduction project that is included in the criteria of an approved or draft recovery plan.

SCIENTIFIC POLICY CONSIDERATIONS IN SPECIES REINTRODUCTIONS AND ECOLOGICAL RESTORATION

The term "policy" carries as many uses as there are users, but in one form or another generally involves asking, "What should we do? How do we propose to act? What are our goals? (Faludi, 1973). In the present instance, identifying a clear long-term *objective* for plant reintroductions is of central importance—an exercise of considerable difficulty. For example, do we intend to maintain *all* species in their current abundance and distribution, or to reduce some and augment others? Do we wish to return all native species to their pre-Columbian distribution and eliminate all exotic invaders? Is the distribution of species intended to remain static or to change over time (and if so, in what way)? Is it our intention, as population biologist John Harper once asked a conservation meeting, "to make rare plants common"? Do we propose to manage habitat actively, or to allow ecological and

Table 3. Nomenclature employed in published literature describing activities involving movement of living organisms to and from habitat, shown with the generally associated level of biological organization.

Term	Level of Biological Organization
Relocation, translocation, transplantation	Individuals, populations
Augmentation, enhancement	Populations
Introduction, reintroduction	Populations, species
Revegetation	Communities
Restoration, rehabilitation, reconstruction	Communities, ecosystems

evolutionary processes to operate without interference (other than the colossal disruption we are already causing by environmental degradation)?

As these questions are meant to illustrate, a true societal consensus on any of these points is highly unlikely. In fact, even within (and between) the conservation and scientific communities there is considerable disagreement on almost every point. Some conservation biologists oppose any moving of organisms, as a disruption of the natural distribution of genetic (and hence evolutionary) variation. Others endorse replacing species in historically documented localities, but only where populations have been recorded previously. Still others encourage placement of threatened species on any suitable protected land, as a pragmatic crisis strategy to prevent further anthropogenic extinction (*see* IUCN, 1987).

"Policy" is not made in the abstract; it represents the collective decisions and intentions of any organized group in society, whether a botanical club, conservation group, mining corporation, trade lobbying organization, or the Federal government. Furthermore, policy is meant to organize behavior in such a way as to promote fulfillment of that group's objectives and mission. But since the objectives and interests of various groups affecting nature may be fundamentally different (and even mutually exclusive), the priority accorded to different goals—such as protecting biological diversity as compared to returning a profit to stockholders—will vary dramatically and predictably. Moreover, one cannot presume to make policy for another group; one can only articulate one's own, and to describe the considerations one believes should be taken into account.

Consideration of these questions for biodiversity management is further complicated by inconsistent and rapidly changing terminology. The literature includes references to introduction, reintroduction, relocation, translocation, transplantation, revegetation, restoration, rehabilitation, augmentation, enhancement, and other terms. Many of these carry specific meanings, while others are used variously or interchangeably. Although the untangling of this nomenclature is beyond the scope of this paper, it is useful to note that each term generally refers to a particular level or range of biological organization (Table 3). For purposes of this paper we will employ the terms "reintroduction" and "restoration" to refer to the relevant actions for populations of rare plants and their associated communities and ecosystems.

Good policy is ultimately dependent upon asking good questions, which are the *sine qua non* of clarity. For that reason, we attempt here to outline some of the basic questions that should be asked, or considerations taken into account, in preparing a reintroduction program. The *questions* are categorical; the *answers* will be case-specific. That is the work of planning a good reintroduction effort.

As a contribution to this process, the Center for Plant Conservation is presently undertaking a national study of reintroduction and mitigation policy with respect to rare plants. This will include a comparative review of the policies of major Federal and State land-managing agencies and private land-owning organizations, and the formulation of proposed guidelines.

In assessing reintroduction as a strategy for conserving rare plants, a series of five areas of inquiry emerge. First, we should always be clear *why* we are undertaking a reintroduction program, and consider carefully what our long-term goal is with respect to the proposed project. Next, we need to consider the *consequences* of a reintroduction effort, including the possible implications for the protection status of existing populations and habitat. Third, we must assess *where* the reintroduction takes place and *who* will be involved in maintaining and managing the population. These considerations have a major bearing on the probable long-term viability and success of the reintroduction effort. Fourth, we need to understand *how* reintroductions should be conceived and carried out from a biological perspective, and the prospect that these actions will contribute to the achievement of a long-term conservation goal. And finally, we must ask *if* reintroduction in a particular case is even technically possible; if not, the option is eliminated from consideration until further research opens the possibility. These five general areas of consideration may be described respectively as (i) objective, (ii) strategic, (iii) managerial, (iv) biological, and (v) technical.

We propose these factors not only as a conceptual framework for thinking about reintroduction and restoration issues, but also as a *decision-making sequence* for well-conceived practical programs. Although we discuss them as separate considerations, we acknowledge that they are highly interactive, and frequently difficult to separate. For example, the absence of a pollinator or seed dispersal agent may raise questions both about the technical feasibility of a reintroduction project, and about its long-term biological significance. Likewise, the strategic consequences of a reintroduction project for the protection of other natural populations may be deeply influenced by administrative factors such as land ownership and the commitment of the land-managing agency to proper ongoing management. Nonetheless, we maintain that reintroductions should above all be well-conceived and well-planned in order to be successful, cost-effective, and contributory to the overall objectives of conservation, and that approaching the planning process in the order described will contribute to prospects for success.

In our experience, many reintroduction efforts begin with careful study of technical feasibility and biological considerations, and only later (or incidentally, or not at all) address the strategic and political consequences of the action. We suggest that this is a significant error, both tactically and procedurally, for several reasons. First, reintroductions should always be undertaken in relation to a clearly stated long-term objective; otherwise, they are simply stochastic events with little prospect for cumulative effect. Second, careful planning can ensure that the project will be carried out efficiently and cost-effectively. Managerial and strategic considerations have a particularly large bearing on prospects for success, both for the immediate reintroduction itself and for protection of other similar populations or communities. And lastly, technical and biological obstacles are the most amenable to resolution by research, experimentation, or simple trial and error; in fact, their resolution may be built into the implementation sequence for the project itself.

1. Objectives

Although it frequently runs counter to our established habitual ways of acting, we submit that thinking about reintroduction programs should start with clarity regarding objectives and strategic implications. Once these overall contextual decisions are made—is reintroduction a good idea? does it meet our long-term objectives?—the more immediate technical and biological concerns may be addressed and incorporated into the project design.

As Millar and Libby (1989) observe, reintroduction and restoration projects can recreate viable, complex, sustainable communities—or "Disneyland" simulations. The determination of long-term objectives is a non-trivial undertaking for anyone working to protect biodiversity in the face of continued development pressure and economic constraints. The days when conservationists could realistically envision large areas of the continent in a wild and natural state are gone, perhaps forever. Instead, we must reorient our efforts to a different set of goals involving the integration of human activities into a matrix of natural biological diversity and functions. As Diamond (1987) notes, even such watchwords as "natural" and "self-sustaining" need to be examined critically and realistically. For many areas of the continent the objective may become to re-establish diversity in a perpetually managed setting—a far cry from self-sustaining, undisturbed systems (Diamond, 1985).

Goal-related issues concerning a reintroduction program might include the following:

1. Are there clearly articulated long-term goals for conservation of the species or community type? What are these goals?
2. Is the goal to re-establish "pre-disturbance" distribution and abundance? If so, what point in the species' or community's natural history do we propose to re-establish? Are distribution and abundance stable, trending, or undergoing long-term oscillation (Falk, 1990a)?
3. What forces influenced the distribution and abundance of the species or community prior to the "disturbance"?
4. Is elimination or amelioration of the cause of decline or threat to species part of the project?
5. Once reintroduction or restoration has taken place, what will happen? Is there a commitment to provide intensive

management indefinitely, or eventually to allow natural successional and ecological forces to prevail?
6. Do we propose to maintain every species and community in perpetuity, or to allow some to change or disappear over time? If the latter, what criteria will we use to make these decisions?

As is evident, some of these questions border on what many practitioners would consider philosophical issues beyond the realm of conservation, or at least beyond their mandate and responsibility. Nothing could be further from the truth; unless these basic issues are addressed and at least partly answered, the efforts of individual agencies with particular sites, species, or communities will have no organized relationship to a long-term goal. Answers may be elusive and difficult to pin down, and the criteria seemingly impossible to establish, but a reintroduction plan will be greatly strengthened by inclusion of these factors in its reasoning, to the extent that they can be addressed.

2. Strategic Considerations

By their very nature, most reintroductions take place in the context of conflicts over land use, enhancing or re-establishing populations destroyed by incompatible uses. Usually at issue is the priority accorded protection of biological diversity versus resource extraction, recreation activities, or other extensive modifications of the landscape. While some of these decisions are made internally by a single agency thinking about its own land, such as the multiple-use paradigm of the Bureau of Land Management or the U.S. Forest Service, most involve conflicting mandates and interests of more than one organization, often in an adversarial relationship.

The most serious contextual consideration for the current practice of reintroduction in the United States is the practice of *mitigation.* Mitigation almost always involves a trade of some kind: land for land, land for money, land for long-term management support. Typically, a developer will propose to establish "new" habitat equivalent to that being destroyed by the project. Variables may include the amount of land involved, financial support, long-term ownership and management responsibility for the created habitat, quality and success assurances, and the relationship to large-scale bioregional strategies for maintaining ecological diversity.

Formally speaking, to "mitigate" means to reduce or ameliorate the impact of an action, to lessen its severity and alleviate or abate its consequences. Many "mitigation" projects are anything but; instead of reducing the impacts of development pressure, in reality they have become a means of justifying *increased* invasion of protected areas. In certain parts of the United States, regulatory agencies now receive hundreds of requests for mitigation projects involving the destruction or substantial modification of natural habitat, in exchange for the creation of "new" habitat elsewhere. On a regional basis, mitigation appears to be most heavily practiced in southern California, peninsular Florida, and parts of the southwest and southeast. Specific habitats, however—notably, wetlands and riparian areas—are being heavily affected in all parts of the country. Wetlands habitats are naturally among the most controversial subjects for mitigation proposals. Given their complex energetic and nutrient webs, species composition, and hydrology, wetlands represent extraordinary challenges for habitat creation or even individual reintroductions (Jarman et al., 1991; Munro, 1991). Yet Dobberteen (1989) found over 1000 wetlands creation projects in Massachusetts alone in just seven years beginning in 1983!

A frequent problem with many mitigation projects is that they are undertaken in the absence of a consensus on long-term goals. For instance, there is considerable evidence that re-created habitats may take decades to become fully established; until this has occurred, there is little assurance that the reintroduced population or created habitat will serve the same ecological and evolutionary functions as those that were destroyed. Long-term issues of land protection may remain unresolved, leaving the reintroduced population or created site vulnerable to future disruption or even destruction. This is especially true for lands under private or corporate ownership.

Most critical, however, is the relationship of mitigation programs to the conservation of existing natural areas. Again, this is fundamentally a matter of agreeing upon objectives. For a developer, the objective may be to build a desired project, and to provide mitigation tradeoffs only to the extent required by law, regulation, political expediency, or a desire to maintain a good public image. Conservationists, on the other hand, may approach mitigation primarily as a strategy to assist the protection of ecologically valuable or unique communities, species, and populations. The regulatory agency involved may operate strictly by the letter of the law, with no particular vision for the future. The overlap between these three different agendas can prove to be narrow ground indeed on which to build a sound future for habitats or threatened species.

By and large, standards for the practice of mitigation projects involving endangered species do not presently exist at the national level. Individual agencies have been developing policies incrementally, but even the largest Federal agencies manifest considerable internal variability in how they approach mitigation proposals. In the meantime, individual states, counties and private corporations all develop, evaluate and implement mitigation proposals in increasing numbers, without the benefit of either a true consensus on goals, or clear national guidelines.

A reasonable starting point for such standards would be that *mitigation projects should never entail the destruction of existing significant and irreplaceable natural areas. Reintroduction and restoration should, in other words, be employed to heal damage that has already been caused, not to rationalize further destruction.* This is analogous to the Hippocratic oath taken by physicians to "do no harm" in using their skills and knowledge (E. Guerrant, pers. comm.). In part, this position reflects a realistic assessment of the uncertainties of ecological restoration; the probability is extremely high that a created habitat or reintroduced population will be different in some essential aspects from the one it replaced, if it succeeds at all. More profoundly, it acknowledges that we still understand very little about the life history, interactions and evolution of most organisms in their natural state, so that a degree of humility is in order before we proclaim "success."

The strategic relationship between existing diversity and proposed reintroductions is especially important for habitats or populations that may be difficult to replicate; in this respect there is a strong linkage between the degree of knowledge about the biology of a species or community proposed for reintroduction, and the strategic implications in undertaking such a project. For example, "no net loss" wetlands policies assume that the technology and scientific understanding reliably exist to create replacement wetlands, when in fact no such knowledge base exists. As Zedler and Langis (1991) observe, decades may be required to ascertain the successful establishment of coastal wetland communities; even then, full functional parity with undisturbed reference wetlands may never occur, due to basic differences in soil or hydrology. For example, their study of natural and constructed wetlands in San Diego Bay found that after five years the constructed wetland areas provided only slightly more than half of the ecological functional equivalency of the natural site, in terms of soil characteristics, nutrient availability, biomass, and species diversity. Furthermore, they saw little evidence that this performance would improve over time.

The same holds true for reintroduction projects with individual rare species. Reintroduction can play a useful role in helping to enhance damaged populations of rare species, to restore extirpated populations, or to establish new ones (Falk, 1990c; Falk and McMahan, 1988; Olwell et al., 1987, 1990). However, it can also be used intentionally by organizations with different objectives to justify the destruction of natural populations. In Western Australia, for instance, the successful results of a state-funded research project into propagation techniques for one of Australia's rarest terrestrial orchids at the Kings Park and Botanical Garden were used in part to rationalize the destruction of one of the few remaining wild populations (Dixon, pers. comm.).

In terms of establishing precedent for the future, mitigation represents a slippery slope. If carried to its logical extreme, any existing natural area could theoretically be subjected to a mitigation tradeoff. Success in restoration and reintroduction work is thus a mixed blessing: while we may celebrate the successful establishment of a new community or population, our very success may be used as a weapon against existing natural areas which we (but not others) are committed to protecting.

Strategic issues that should be raised in evaluating a restoration or reintroduction project thus may include:

1. Is the project consistent with large-scale regional strategies for protecting land and biological diversity (Jenkins, 1989)? Will the project establish a precedent that might indirectly weaken protection for other natural areas?
2. Will the project *directly* involve the destruction of any existing natural area? If so, what is the comparative quality of the proposed sacrifice and replacement areas? What are the chances that unique biological or landscape values will be

lost if the project proceeds? Are there any alternatives to this course of action?

3. What criteria were used in selecting the sacrifice area? Are they biologically sound and contribute to overall conservation objectives as identified in Step 1, Objectives, above?
4. Can impacts be directed to areas already disturbed and away from previously undisturbed sites?
5. How much acreage is involved in destruction and creation? Have sufficient areas been included for buffer zones, large-scale ecological processes, and movement of communities over time?
6. Has the project been costed-out over a realistic long-term financial schedule (King, 1991)? Is there a substantial net gain in funds available for conservation projects? How will unexpected future costs be borne, and by whom? Have performance bonds been posted that correspond to the time required to assess biological success?
7. Are there binding commitments by the land-managing agencies for permanent protection of the created habitat or reintroduced populations? What provisions have been made for monitoring and management (see Step 3, below).

3. Land Management and Administration

Introductions will most likely be of permanent conservation value if they are undertaken on land that is securely protected and managed for biological values. Long-term management in some form is essential for the maintenance of natural diversity on most protected areas in the continental United States, including even our largest natural areas and parks (e.g., Clark and Harvey, 1988). The "managed natural area" is no longer considered an oxymoron, but rather the dominant mode of preserving land and ecological values.

Management considerations are especially important for reintroduced populations of rare plants. Many species inhabit successional communities, or habitat parcels so severely fragmented that only intensive management can maintain their integrity. Reintroduction experience with *Pediocactus knowltonii, Penstemon barrettiae, Dicerandra immaculata, Stephanomeria malheurensis, Arctostaphylos uva-ursi* var. *leobreweri, Amsonia kearneyana, Styrax texana, Amsinckia grandiflora* and other species confirms the importance of having a long-term management plan for a reintroduction site.

The case of *Stephanomeria malheurensis* (malheur wire-lettuce) provides a good case in point. The plant, which is of considerable scientific interest because of evidence that it is recently speciated (Gottlieb, 1973, 1991), is known only from its type locality in south-central Oregon. The population was virtually destroyed in the 1980's by grazing, fire and invasion by exotic species. Using seed collected at the time of the species' original description, the Berry Botanic Garden collaborated with the U.S. Fish and Wildlife Service, Bureau of Land Management, Center for Plant Conservation and others to re-establish the plant on the original site. Transplants were undertaken using four experimental ground covers, with the area fenced by the BLM. For the foreseeable future, the species will have a chance only if management measures are maintained; otherwise, the same forces that brought about its demise once would almost certainly do so again (Parenti and Guerrant, 1990). Such cases are more likely to be the rule than the exception with rare species reintroductions.

Several private companies have introduced or reintroduced rare species onto their lands following major disturbances from mining or construction operations. Such work is frequently mandated by state or Federal law and generally carried out as part of a master plan for post-mining land reclamation (Gillis, 1991). However, there is frequently a reluctance to establish, in the words of the environmental officer for one such firm, "species that carry a regulatory burden"—in other words, restrict the company's options for future land use. Given the weakness of the Endangered Species Act in its present form to protect plant species on private land, reintroduced populations on non-conservation land should probably be regarded as ephemeral unless the company is willing to sign a long-term conservation contract with a public agency or conservation group.

On the other hand, reintroduction can play a significant role in the recovery of endangered or threatened species, if integrated into long-term planning. An example is *Trifolium stoloniferum* (running buffalo-clover), for which a strategic recovery plan has been developed by the U.S. Fish and Wildlife Service, integrating legal status, site protection, establishment of reintroduced or enhanced populations and research (U.S. Fish and Wildlife Service, 1989).

Administrative and management considerations in planning reintroductions may include the following:

1. Does a recovery plan exist? If so, did the agencies responsible for implementation play a part in its formulation, and have they made a commitment to carry it out?
2. Is the reintroduction site under secure long-term protection?
3. Has the original threat(s) to the species or community been eliminated, or are there plans to manage the threat(s)?
4. What is the commitment of the land-managing agency to conservation and biological management? Is such activity basic or incidental to its primary interest?
5. Will there be on-going monitoring and management of the site? Will such activities maintain habitat for the species in question?

4. Biological Issues

Despite elevated public interest and attention in rare species, the base of knowledge about rare plants remains small. The first comprehensive volume on the subject (Falk and Holsinger, 1991) includes discussion of the genetics, population biology, demography and ecology of rare plants to the extent they are known, but in general one is struck by how little published data exist for most rare species. Symposia organized by the California Native Plant Society (Elias, 1987), Natural Areas Association (Mitchell et al., 1990), and Society for Ecological Restoration (Bowles and Whelan, 1992) have contributed a great deal of new information, as have research reports in the conservation biology literature. Specific aspects of the biology of rare plants in some genera—*Amsinckia, Astragalus, Calochortus, Cercocarpus, Clarkia, Helianthus, Pediocactus, Pedicularis, Platanthera* and *Stephanomeria,* for example—have been studied closely by one or more researchers, and there are now several hundred published citations of specific rare plant studies. But with over 4400 rare species in the United States alone, distributed in nearly 1000 genera, this is a thin knowledge base from which to successfully manage this diversity of species.

Much information about rare species remains anecdotal and unrecorded except for the internal documents and contracted reports of managing agencies. Recovery plans of the U.S. Fish and

Wildlife Service help to draw together references for individual species, but here again fewer than 6% of species of national conservation concern have been listed under the Endangered Species Act, and only half of those as noted above, have recovery plans. The detailed empirical observations of sanctuary and preserve managers, agency field staff, conservation horticulturists and amateur botanists are all of great value, but all too often these insights go unrecorded, and hence remain unavailable to all but a few people. Intensive research studies (such as Bowles, 1983) are extremely useful for reintroduction work; however, few rare plant species have ecological studies in sufficient detail.

Clearly, it will often be impractical to assemble a complete biological profile of every species or community before we begin engaging in conservation work. Consequently rare plant reintroductions will involve a substantial element of trial and error experimentation (Harper, 1987; Griffith et al., 1989). Unlike well-studied crops or range grasses, field reintroductions of rare plants involve species whose developmental, reproductive and ecological characteristics are little known. Information critical to understanding how to design an appropriate reintroduction, including the original biogeographic distribution, pollinators and seed dispersal agents, genetic architecture and long-term patterns of population growth, may be unknown. Present patterns of distribution may be so severely disrupted by anthropogenic causes that even the plants' preferred soil type may not be reliably determined. For example, the tallgrass prairie flora of the Great Plains now remains in such a small fraction of its original extent, and in such fragmented parcels of habitat, that it is difficult to know even which species were naturally rare and which were reduced to rarity by habitat modification. In Illinois, less than seven hundredths of one percent of the original prairie remains intact (White, 1978). Some entire communities, such as the tallgrass savannas, were virtually invisible because they had become so overgrown and invaded (Packard, 1991).

A classic New England example of the need for deeper biological understanding is the attempted translocation of *Isotria medeoloides* (small whorled pogonia) from a naturally occurring (but unprotected) site on the west side of Lake Winnipesaukee, New Hampshire, to nearby protected state land (Wilson, 1987). Originally undertaken to salvage plants from a condominium development on private land beginning in 1985, the reintroduced plants have been monitored for recruitment, mortality and other parameters. The species is known to undergo long-phase oscillations in reproductive population (Mehrhoff, 1989), further complicating assessment of the size or status of the population at any given time; it is frequently difficult to distinguish such long-phase oscillations from linear trends for decline or increase in population size (Brumback, pers. comm.). Thus, a proposal to confidently relocate this species as part of a mitigation project would have to be met with considerable skepticism, patience, or both.

Most rare plant reintroductions involve outplanting of a subset of the genetic variation found within the species. As such, these efforts constitute empirical tests of several important hypotheses in population biology related to the genetic and evolutionary consequences of small population size: founder events and genetic bottlenecks, the effects of close inbreeding and the vulnerability of small populations to various types of stochasticity (Barrett and Kohn, 1991; Menges, 1991; Lewin, 1989). Although a few rare plant reintroductions (such as *Amsinckia grandiflora* by Pavlik, *Stephanomeria malheurensis* using material provided by Gottlieb, and *Hymenoxys acaulis* by De Mauro) have been carried out with baseline genetic data on the reintroduced individuals, until recently few have included such data or any provision to monitor changes in the genetic structure of the population over time. The result is two-fold: (i) collective knowledge of rare plants is not expanding as rapidly as it might; and (ii) many reintroductions will fail biologically for reasons that will not be fully understood.

In general, the rare plant literature supports the view that genetic variation found among populations is significant reproductively, ecologically and evolutionarily, and should be maintained in conservation work (Holsinger and Gottlieb, 1991; Templeton, 1991; Hamrick et al., 1991). Small differences among populations may represent incipient ecotypic differentiation or even the beginning of the speciation process. Moreover, a significant fraction of the total diversity in plants is found among populations (Hamrick et al., 1991). Approximately half of the allozyme loci in plants, on the average, are polymorphic (although endemic species are somewhat lower, with approximately 40% of their loci polymorphic). Twenty two percent of this diversity is distributed *among* populations, influenced to some degree by ecological and life-history factors. Huenneke (1991) notes the ecological significance of genetic variation within and among populations for microhabitat differentiation, resistance to pathogens and herbivores, and overall ecological amplitude. And Menges (1991) has described the correlation between low genetic variability in populations and increased vulnerability to genetic, environmental, catastrophic and demographic stochastic events.

Although direct experimental confirmation of these assertions remains scattered, genetic variation should be a major factor in designing reintroduction programs (Templeton, 1990). As Holsinger (1991) observes, although the genetic architecture of most rare species has not been studied directly, the existing literature does permit reasonable generalizations. For example, outcrossing species on the whole exhibit a higher proportion of polymorphic loci (p) and more alleles per polymorphic locus (A) than do selfing species; conversely, selfing species distribute a far higher proportion of their variation *among* populations (G_{st}) than do outcrossers. These and other general observations should permit the design of reasonably effective genetic sampling programs, especially given the small number of natural populations for most rare plants. Propagules should be drawn from several populations, and from a sufficient number of individuals within each population, to ensure that the majority of genetic variation at polymorphic loci has been captured. Several sampling strategies have been proposed for rare plants (*see*: Brown and Briggs, 1991; Center for Plant Conservation, 1991; Guerrant, 1992). Reintroduction plans should reflect conscious decisions about the size of reintroduced populations; artificially small populations may be considerably more vulnerable to stochastic events, drift and inbreeding depression, particularly in species that are not adapted to small population size in the wild. Guerrant (1992) observes that many reintroduction programs should involve the establishment of several experimental populations, to guard against environmental and genetic stochasticity, and to exploit microclimatic differences.

Among the major biological considerations in rare plant reintroductions are:

1. What is known about the genetic structure of the species, within and among populations? Can assessment of this variation be built into the project design?
2. What is known about the population biology and demography of the species, including effective breeding popula-

tion size? What short- and long-cycle fluctuations in these values are observed in natural populations?

3. How many experimental outplant sites should there be?
4. From which populations should propagules be drawn? Should genetic material from several populations be combined or kept isolated?
5. Is the species endemic to certain edaphic types? Can it survive elsewhere if competition is controlled? Do the edaphic tendencies appear to be obligatory? Are these observations consistent for all populations?
6. What are the essential symbionts: pollinators, seed dispersants, mycorrhizal fungi, others?
7. What is the species breeding system? Is propagation largely sexual, asexual, mixed, or variable? What is the likelihood that the population will be able to establish itself reproductively on the new site?
8. What are the viability characteristics of the seeds? What dormancy mechanisms exist, and how is dormancy broken? What proportion of the genepool remains as ungerminated seed in the soil seed bank (Glass, 1989)?
9. What are the optimal environmental conditions for seedling growth? How much tolerance does the species have for conditions different from the optima?
10. Is the species characteristic of successional environments? Can it survive elsewhere if competition is controlled?
11. What is the species' "natural" range? What factors, natural and anthropogenic, limit its distribution?

5. Technical Feasibility

Consideration of the finer points of context and strategy will be largely academic if a reintroduction project is not technically possible. Feasibility certainly represents an absolute prerequisite for any actual on-the-ground activity and should be borne in mind throughout the planning process. Nonetheless, we have reserved this section for last because we believe that the feasibility of a project should not necessarily determine its priority or desirability. In other words, simply because reintroduction *can* be done does not mean it necessarily *should* be done.

Technical considerations grade strongly into the basic issues of biology discussed in the preceding step. For instance, lack of understanding about seed dormancy, pollinators, or edaphic requirements may raise questions about the biology of a project, but such unknowns also create uncertainty about its feasibility. Moreover, short-term success may not mean that long-term technical problems have been solved. For instance, a recent study of California coastal sage scrub indicated that, although there was evidence of scrub seedling regeneration in the first few years of the project, the true success of the reintroduction could not be reliably assessed for 30–50 years. Similar caveats have been raised for community restorations and population reintroductions in prairies, woodlands and riparian areas (*see* essays in Jordan et al., 1987). Technical feasibility of the off-site cultivation phase may also play a part in the planning and reintroduction process for sub-tropical species, as Wallace (1990) has described for sand scrub endemics of peninsular Florida.

A review of reintroduction and restoration literature reveals a wide assortment of technical considerations for successful reintroduction practice. Most considerations are highly specific to a species or habitat type (e.g., Tipton and Taylor, 1984), but a few general considerations emerge as significant:

1. Does a reliable source of reintroduction material exist, either in a natural population or off-site conservation collection? If the latter, are provenance, genetic composition and curatorial history known?
2. If collecting propagules from a wild population is required, do plants exist in sufficient numbers? Is the population reproducing, and if so are seeds or vegetative propagules produced in sufficient quantity to permit removal without interfering with reproduction?
3. Can material be reliably propagated to a stage that permits transplanting? Is there a dormancy requirement before seeds will germinate?
4. Are propagules disease-free? Is there any possibility of importing diseases inadvertently into the new habitat, or if augmenting a population, into existing habitat?
5. Are techniques for transplanting material known? Is there evidence that transplants will survive? What sort of interim management measures, such as watering, will be required in the early stages?
6. Is the recipient site free of threats or disturbances that might

compromise the prospects for success? Is the site stabilized physically from erosion? Is the recipient community invaded by exotic organisms that might reduce the likelihood of success?

CONCLUSION

Increasing destruction, disturbance and fragmentation of remaining pristine habitat require that alternative strategies be sought rapidly and incorporated into strategic planning for biodiversity. Reintroduction and restoration represent important tools for the preservation of biological diversity in its ecological and evolutionary context (Falk, 1992), as well as suggesting a more balanced and creative relationship of human society to nature than industrial societies have achieved to date (Jordan, 1986). It is imperative that practitioners of these important techniques remain clear about the strategic implications of their actions, to ensure that the work of restoration contributes positively to the continuation of the diversity of life on Earth.

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CENTER FOR PLANT CONSERVATION
MISSOURI BOTANICAL GARDEN
P.O. BOX 299
ST. LOUIS, MO 63166